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A SUMMARY OF EYE-PROTECTION DEVICES AGAINST NUCLEAR EXPLOSIONS

JAMES E. HAMILTON, Captain, USAF, BSC, MS, OD

May 1966

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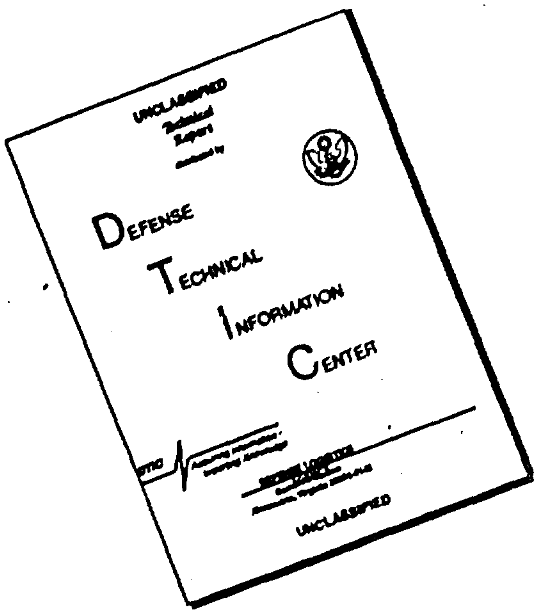

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A SUMMARY OF EYE-PROTECTION DEVICES

AGAINST NUCLEAR EXPLOSIONS

JAMES E. HAMILTON, Captain, USAF, BSC, MS, OD

FOREWORD

This report was prepared in the Ophthalmology Branch under Task 630103. The work was accomplished from August 1964 to May 1966. The paper was submitted for publication on 31 May 1966.

The professional assistance of Everett O. Richey and Major Lester R. Loper is gratefully acknowledged. The technical assistance of Airman Second Class Peter C. Hesslink in a seemingly endless library search for publications is also gratefully acknowledged.

ABSTRACT

A bibliography of eye protection from flashblindness and retinal burn is compiled from work that has been done in this area. In addition, each principle of eye protection is explained and the most significant examples of each principle are given. Some fixed filters worn during daylight hours will protect the eyes from flashblindness and retinal burn. Protection for the eyes still remains unsolved for scotopic vision.

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A SUMMARY OF EYE-PROTECTION DEVICES AGAINST NUCLEAR EXPLOSIONS

I. INTRODUCTION

In the event of another war, air operations may be entirely different from those experienced in previous combat operations. Pilots may be exposed to flashes from nuclear weapons. These flashes can cause flashblindness or even permanent retinal damage under certain conditions. For aircraft on low level missions even a brief impairment of vision may cause complete failure of the mission (1).

Flashblindness may be defined as the temporary loss of vision produced by the overstimulation of the photoreceptor cells of the eye. A nuclear flash causes the eyes to become incapacitated to the point where useful vision may not be acquired for many seconds following the flash. During this time a pilot may be unable to see the instruments in his cockpit or the terrain below the aircraft.

Permanent retinal burns are caused by the absorption of thermal energy in the retinal pigment and underlying layers. Permanent loss of vision may be serious in such cases.

For several years the U.S. Air Force has been supporting research with the goal of developing a method to provide a pilot with protection against flashblindness resulting from exposure to a nuclear weapon. The following basic design criteria have been given by the Air Force to provide this protection: (a) Open state optical density not greater than 0.30; (b) Closed state optical density greater than 3.0 in 150 microseconds uniform over the surface with $\pm$ 0.1 optical density. It is unknown whether devices presently under development will or will not meet the required basic design criteria.

Many studies have been made concerning eye protection from high intensity light sources describing the development of specific protective devices. Eye protective devices that have been developed may be classified according to their method of operation: fixed filters; electro-mechanical; electro-optical; explosive lens filter; and phototropic devices.

Fixed filter (F). Over two dozen studies have been made on this type of filter within the past ten years. Homogeneous, coated, and louvered materials have been incorporated into shields, goggles, hoods, visors, masks, periscopes, and other optical instruments. Most fixed filters are not completely satisfactory because a filter dense enough to assure protection from a nuclear flash is too dense to be worn constantly. This is especially a problem at night when fixed filters of any kind greatly reduce visibility and the naturally dilated pupils admit more energy to enhance the production of flashblindness and retinal burn. Louvered screens are bulky and offer only limited protection. Since donning of the various devices is largely manual, no protection is provided for unexpected blasts. A good example of the fixed filter type of protection (2) is the 3% gold-plated visor which can be incorporated into the pilot's flying helmet. These visors have a relatively high transmission of the visible spectrum compared with the ultraviolet and infrared regions of the spectrum. During daylight hours this gold-plated visor does not reduce the ability to detect high contrast targets. A 2% gold-plated visor has been accepted for general use in the United States Air Force for flying personnel.

Electro-mechanical (E-M). Approximately a dozen studies have been made on devices based on this principle of operation. This type of device must be triggered by a sensor which detects light from a nuclear blast and electrically triggers an explosive cartridge to close a shutter. Although some of these systems close on the order of several hundred microseconds to a few milliseconds, they offer only limited protection. These devices are bulky and limit vision to some extent in the open state. One good example (3) of this device is an electro-mechanical goggle in which each eyepiece of the goggle contains two lenses, one of which is movable over the other. Each lens has opaque vertical bars on its surface and when the bars are superimposed the goggles provide approximately 30% or more light transmission. A nuclear flash is detected by photocells that trigger a power pack which in turn supplies the energy to set off a charge in an explosive piston motor attached to the goggles. The piston drives a cone-shaped wedge downward causing the movable lens in each eyepiece to move laterally. The opaque bars on one lens then coincide with the transparent spaces on the other, resulting in less than 0.01% transmission within 500 microseconds.

Electro-optical (E-O). Approximately a dozen studies have been done on devices employing an electro-optical principle to increase the density of optical materials when exposed to nuclear blasts. The light flash from a nuclear detonation is converted to an electrical signal which in turn activates a Kerr cell or other polarizing device. Closure time is in the order of microseconds to milliseconds. These devices are bulky and limit vision to some extent in the open state. The stressed-plate shutter device is an "active" filter evaluated by the U. S. Army Ordnance Frankford Arsenal (4). It consists of a Hayward glass plate mounted between a pair of polaroid filters. The assembly is then bonded to a pair of rigid tungsten carbide horizontal beams. Vertically between both ends of the beams are stacks of piezo-electric ceramic wafers. As long as current is applied to the system, there is 20% transmission of light. A nuclear flash triggers a sensing device which in turn cuts off the current, closing the system. A 0.04% transmission can be obtained in 100 microseconds. The system does not need manual recharging or rearming.

Explosive lens filter (ELF). Only a few studies have been made employing the explosive lens principle. Light from a nuclear blast is detected and triggers an electronic circuit which detonates a charge. This explosion ruptures a membrane and scatters an opaque liquid or solid throughout the entire optical system. The most important advantage of the explosive lens principle is that the open state transmission is quite high; thus, they may be used on night missions. However, the explosive lens must be replaced after each use. The ELF (Explosively-Actuated Light Filter System) (5) offers promise for immediate operational use. This system has several automatically operated components. The ELF system contains goggles with clear lenses designed to be closed automatically by a signal from a sensing unit. When the appropriate signal is received, a carbon colloid solution is explosively driven between layers of the lens, effectively blocking all light transmission. The closing time is very rapid, thus effectively blocking out much of the light from a nuclear explosion. The ELF goggle assembly is incorporated into the pilot's flying helmet, and may be moved up on the helmet at any time, allowing complete freedom of vision when desired.

Immediately after closing operation of the ELF system, the pilot may enclose himself within a protective hood inside the cockpit, raise the lens assembly, and go on instruments using necessary cockpit illumination. At his leisure, he can unsnap the opaque visor and replace it with a fresh transparent one, after which he can open the protective hood and be protected in the event of another flash.

Phototropic (P). Many studies have been made on photochromic materials. These materials change color and transmission characteristics on exposure to light. Some materials start to increase in density within a few microseconds after exposure to a light flash and then as a rule begin to decrease in density upon removal of the light. Since liquid filters are bulky, there is a need for this material to be converted to a solid or a gel state. Phototropic materials may have a short shelf life and have a relatively low transmission in the open state. Since they require a large amount of energy for activation, small areas such as goggles may be more practical than use in entire canopies. One prototype phototropic goggle system (6) recently completed holds considerable promise. The goggles consist primarily of quartz wedges with a phototropic material held in solution between the wedges. A light source is positioned at the edge of the quartz lens system. A sensing unit responds to the nuclear burst and in turn causes the flash unit to operate and shine down the quartz wedges. The phototropic material provides protection against radiation within the visible spectrum. It does not, in most cases, provide protection from radiation outside the visible spectrum and side-band filters are required.

II. DISCUSSION

Let us now consider what has been done to date and what still needs to be done.

During daylight hours a 2% transmission fixed filter gold-plated visor allows comfortable unobstructed vision, gives adequate protection against retinal burns under test conditions, and significantly reduces flashblindness duration to 10 seconds or less under most conditions. This visor replaces the clear visor in a standard U. S. Air Force helmet.

The use of automatically activated auxiliary instrument panel lighting of 125 ft. c. is a helpful countermeasure for flashblindness at night. The lighting does not prevent flashblindness, but does significantly reduce recovery time.

There is at present no satisfactory protection from flashblindness when exposed to nuclear flashes under nighttime conditions. Even though we are closely approaching the time criteria with the ELF goggle (5,7,8) and with the indirectly activated photochromic material (6,9), these devices are not as operationally feasible as the device used for daylight protection. A fixed filter like the 2% transmission gold visor cannot be used under scotopic conditions because it significantly reduces visual acuity under those conditions.

The ultimate protective device would be an automatically reversible directly activated visor that would meet the basic U. S. Air Force design characteristics in time and density. It could be worn comfortably in the flying helmet without visual obstruction both day and night. This would eliminate the need for the daytime 2% transmission gold visor and the auxiliary instrument panel lighting. It could be used for protection from flashblindness and retinal burns due to visual exposure to nuclear flashes. It could also be used for protection from flashblindness caused by lightning flashes at night, flying toward the sun, or flying near snow-covered terrain during the day. All known directly activated reversible photochromic filters do not have the required sensitivity to fulfill these requirements at all unsafe distances from a nuclear flash.

The purpose of this report is to provide a basic outline (Table of Contents, Part III), of eye protection ranging from the simple application of protection from sunlight to the more complicated classes of systems specifically designed for eye protection from nuclear flashes. A summary of the developments within each of these classes and a bibliography of 108 relevant reports are also provided.

Some items in this report were not intended for nuclear flash protection and appear to provide no useful information relative to the report topic or appear to have no connection with nuclear eye protection. However, almost any type of optical filter will provide some limited degree of protection from flashblindness and retinal burn. Basic methods of obtaining optical density in a protective device and its application to the eye is very important if a comprehensive study of eye protection from nuclear flashes is to be made.

III. SUMMARY CHART

This report does not attempt to evaluate or assess the usefulness of the various devices listed. The results and conclusions reported are primarily those of the original authors.

A. Fixed filters (F)

1. Miosis

Manufacturer: Not applicable
Author: Minners, H. A., and N. L. Newton (10)
Light transmission: 1 mm. pupil = 1% (density 2.0)
to
10 mm. pupil = 100% (density 0.0)
(Disregarding absorption and reflectance of the transparent optical media of the eye.)
Operating time: Constant
Principle: Miosis. Based on the laws of optics, miosis limits the quantity of light entering the eye and is, therefore, equivalent to neutral filters. Thus, miosis should afford chorioretinal thermal protection.
Method of operation: When a partially dark adapted retina is exposed to a given diffuse flash of visible light energy with the pupil dilated, 30 sec. may be needed to regain adequate visual discrimination. The same retina with a constricted pupil and exposed to the same flash may require only 18 sec. to regain adequate visual discrimination.
Results and conclusions: Before either drug or artificial miosis can be recommended for field use, several other aspects of this approach must be investigated.

2. Monocular eyeshields

a. Manufacturer: Procured through regular medical supply channels (item FSN-6515-367-0420)
Author: Wilson, C. L.(11)
Light transmission: Constant 0.001% to 0.0001% (density 5 to 6)
Operating time: Manually operated
Principle: Monocular eyeshield of a fixed density. The device should be painted with zinc chromate primer on the inside and with black enamel paint on the outside. In addition, it should be fitted with a styrofoam cushion on the inside. The eyeshield is held in place over the eye by an elastic band which encircles the head.
Method of operation: It is anticipated that when the pilot and copilot use the eye shade they will wear a shield over one eye. The pilot will be looking out of the aircraft and the copilot will be monitoring the instruments. Combat crews plan for both pilot and copilot to open front thermal curtains and for each one to use both eyes during refueling. Crew members are to wear a modified eyeshield whenever possible while the thermal curtains are open.
Results and conclusions: The device is readily available, inexpensive, light weight, comfortable, and easily worn with flying helmet. It is not easily worn with glasses. (Loss of vision in one eye is not a solution to the problem.) No further report.

b. Manufacturer: Not applicable
Author: Provost, J. R. and R. Noble (12)
Light transmission: Less than 0.001% (density 5+)
Operating time: Manually operated
Principle: Monocular eyeshield of a fixed density. Retractable patch is attached to flying helmet.
Method of operation: Method of operation is similar to 2a.
Results and conclusions: Loss of vision in one eye is not a solution to the problem.

3. Coated materials

a. Manufacturer: Polacoat, Inc.
Author: Baltzer, D. H., and J. F. Dreyer (13)
Light transmission: Constant daylight transmittance of 15% $\pm$ 3% (density about 0.8)
Operating time: Manually operated
Principle: Coated plastic lenses. Coating technics and materials for the manufacture of uniform density plastic prescription sunglasses have been investigated.
Method of operation: Coating by a spinning technic utilizing a formulated nitrocellulose compound was found to give the best results.
Results and conclusions: Ultraviolet cutoff at 390 mμ, near infrared spectral transmittance below 50% between 700 and 1200 mμ. Pencil hardness 2H to 3H.

b. Manufacturer: Unknown
Author: Banet, L. (14,15)
Light transmission: Any field transmission of less than 100% (any field density of more than 0)
Operating time: Manually operated
Principle: Coated-glass lenses. Investigation of several coatings of the lenses.
Method of operation: Can be used as goggles, glasses, in periscopes, and in other optical devices.
Results and conclusions: Some coatings scratch easily, are not resistant to metal sparks, and are expensive to manufacture.

c. Manufacturer: Unknown
Author: Jones, W. L., and J. F. Parker (8)
Light transmission: 1% (density 2)
Operating time: Manually operated
Principle: Even-density lenses. 1% neutral-density, gold-coated filter. Same as 1% neutral-density, gold-coated goggles and visors.
Method of operation: Not applicable
Results and conclusions: Unaccepted by the U. S. Navy.

d. Manufacturer: Bausch and Lomb
Author: Bausch and Lomb
Light transmission: Unknown
Operating time: Manually operated
Principle: Contrasting density lenses. Sungalsses of highly reflective coated lenses with shape of instrument panel uncoated in lower half of lenses.
Method of operation: Instrument panel falls within the field of view through the uncoated part of the lenses.
Results and conclusions: These glasses are good for use in daytime only.

e. Manufacturer: American Optical Company
Author: Jupnik, H. (16)
Light transmission: 50% at bottom of lens to less than 0.31% at the top (density 0.3 at bottom and 2.5 ± 0.3 at top)
Operating time: Manually operated
Principle: Gradient density lenses
Method of operation: Sunglasses in which the instrument panel falls within the field of view through the least dense part of the lenses.
Results and conclusions: Coatings passed the Jan-F-675 abrasion test and the specified scotch tape test. These glasses are good for daytime use only.

4. Goggles

a. Manufacturer: American Optical Co.
Author: Jacobs, E. P. (17) and Hill, J. H. (18)
Light transmission: 1.1 - 1.2% (density about 2)
Operating time: Manually operated
Principle: Goggles. Enconel-filtered [sic] red lenses mounted in goggles designed to provide a light-seal when used alone or in conjunction with various types of protective helmets. High red light transmission is provided for reading red-lighted aircraft instruments or a selective spectral filter could be utilized.
Method of operation: Not applicable
Results and conclusions: It has been recommended that LRFG-58 goggles be withdrawn from service use as aviator's equipment because they are uncomfortable, fog, restrict field of view, and cause loss of color vision.

b. Manufacturer: Unknown
Author: Moore, J. L. (19)
Light transmission: 1% (density 2)
Operating time: Manually operated
Principle: Low-density, filter-type goggles
Method of operation: Goggles to be worn with an aviator's helmet--a combination filter-reflective system
Results and conclusions: Recommended for service use if cockpit illumination was to be provided, and if goggles were trimmed to better fit helmet. (A 2% gold visor has recently satisfied requirements for protection during the daytime for the USAF.

5. Optical insert

Manufacturer: Unknown
Author: Colman, A. B. (20)
Light transmission: Unknown
Operating time: Manually operated
Principle: Optical insert. To be used as a vision-corrective device when worn with the following CBR protective masks: (1) M14A2 Tank Protective; (2) M17 Military Protective; (3) M24 Aircrewman's Protective.
Method of operation: Optical insert-type 3R1 may be used as filters of visible light.
Results and conclusions: It is not known whether a prototype model has been constructed.

6. Visors

Manufacturer: BioTechnology, Inc.
Author: Parker, J. F., Jr. (2)
Light transmission: 1%, 3%, and 15% (densities 2, 1.5, and 0.82)
Operating time: Manually operated
Principle: Fixed filter visors. These visors are to be worn in connection with aviator's helmet. Several types have been designed.
Method of operation: Not applicable
Results and conclusions: Gold films have a relatively high transmission of the visible spectrum compared with ultraviolet and infrared regions under normal daylight conditions. Visors tested did not reduce ability to detect high contrast targets. For solid overcast, dusk, dawn, and night, vision decreases as visor density increases. (A 2% gold visor has recently satisfied requirements for protection during the daytime for the U.S. Air Force.)

7. Face covers

a. Manufacturer: Mine Safety Appliances Co.
Author: Timm, W. (21)
Light transmission: Unknown
Operating time: Manually operated
Principle: Face mask. Suitable ballistic protective goggles with face mask used as a shield against eye burns and energy levels three times greater than the bare skin can tolerate.
Method of operation: A louvered screening material is incorporated into a face mask. Louvers have been set at 62 degrees from the horizontal with mesh shields at both sides. A louvered screen incorporated into a layer of ballistics material was later added.
Results and conclusions: The mask is bulky and restricts field of view.

b. Manufacturer: American Optical Company
Author: American Optical Company
Light transmission: Unknown
Operating time: Manually operated
Principle: A face shield to be used with the electro-VADO shutter which was developed by Marks Polarized Corporation
Method of operation: Not applicable
Results and conclusions: It is not known whether further testing was done.

8. Hood

Manufacturer: Unknown
Author: Jones, W. L. and J. F. Parker (8)
Light transmission: Unknown
Operating time: Manually; later model to close automatically
Principle: Protective hood. The frangible hood extends from the instrument glare shield to the area around the viewer. The hood is angled along the instrument eye-reference line.
Method of operation: Hood is designed to be closed by pilot; later models will close automatically.
Results and conclusions: Some measure of protection from flashblindness will be afforded, particularly from those weapons which produce extended fireballs.

9. Thermal shield

Manufacturer: Unknown
Author: Chisum, G. and J. H. Hill (7)
Light transmission: Closed - 0% (density more than 5)
Open - 100% (density 0)
Operating time: Manually; later model to close automatically
Principle: Thermal shield. Buggy-top shield to be used in conjunction with ELF goggles
Method of operation: Thermal shield closes manually or automatically after ELF goggles have been activated in the helmet visor. Visor is then removed and the pilot flies instruments until new visor is fixed in place and thermal shield is opened manually.
Results and conclusions: Space limitations of the A4D cockpit with the protective thermal shield closed are severe.

B. Electro-mechanical (E-M)

1. Shutters

a. Manufacturer: J. W. Fecker, Inc.
Author: J. W. Fecker, Inc.
Light transmission: Closed - 0% (density more than 5)
Open - unknown
Operating time: To close - time order of microseconds
To open - manually operated
Principle: Electro-mechanical shutter. An optical viewing periscope permitting outside vision through a 1-inch slot.
Method of operation: The device has a cylindrical lens system whereby a pair of mirrors serve as reflectors. A guillotine shutter device is under development which will be installed and which can be closed manually, automatically, or both.
Results and conclusions: This device is a comparatively heavy unit with a limited field of vision capability. The system has a field of view $\pm$ 40° to $\pm$ 30° vertically and a little better than $\pm$ 60° laterally. It is not known whether the instrument was ever built.

b. Manufacturer: Not applicable
Author: Pisano, F. (22)
Light transmission: Closed - 0% (density more than 5)
Open - unknown
Operating time: To close - 480 microseconds
To open - unknown
Principle: A shutter to close an optical aperture 6 3/4 inch by 2 1/4 inch within a time interval of 480 microseconds
Method of operation: Optical shutter was explosively activated; triggering mechanism was the T20E1 detonator.
Results and conclusions: Two working models and ten shutters were fabricated. Closure within 480 microseconds was reported. Additional development was recommended.

c. Manufacturer: Fairchild Camera and Instrument Corp.
Author: Moatz, D. R. and D. A. Jones (23)
Light transmission: Closed - 0% (density more than 5)
Open - unknown
Operating time: To close - 100 to 500 microseconds
To open - manually operated
Principle: Cartridge-activated curtain shutter as a flash protection system for a T-50 tank periscope.
Method of operation: The device senses light from a nuclear flash and detonates explosive charge to close shutter.
Results and conclusions: It was concluded that 100 microsecond closure for small aperture and 500 microsecond closure for large aperture were feasible.

2. Goggles

a. Manufacturer: Renauld of Reno
Author: Goldish, L. H. (24); also see Ref. (25)
Light transmission: Unknown
Operating time: May be opened or closed in the time required to manually rotate a knob on the bridge of the glasses. It is unknown if a small photocell-driven motor, which could be attached to the glasses, has ever been tested. An activator of this type would reduce operating time from the time required for manual operation.
Principle: Rotating lens polarizer glasses in which each lens is composed of a pair of polarizers that can be rotated on an axis running through the geometric center of the lens from a state of minimum to maximum transmission.
Method of operation: The pair of polarizers in each lens can be rotated by means of a knob on the bridge of the glasses. It is possible to attach a small photocell-driven motor to the frame of the glasses.
Results and conclusions: A similar scaled-up system could probably be built into a telescope or a window, although open-state transmission is limited by the transmission of uncrossed polarizers.

b. Manufacturer: Electronic Corp. of America (early model), Wayne-George Corp. and National Cash Register Co.
Author: Electronic Corp. of America (26), Wayne-George Corp. (27), Burger, N. R. and H. C. Filer (3) and M. G. Bowling (28)
Light transmission: Closed - 0.01% (density 4)
Open - 30% + (density less than 0.52)
Operating time: To close - less than 500 microseconds
To open - manually reset by rotation of motor housing
Principle: Electromechanical goggles. Each eyepiece of the goggle contains two lenses, one fixed and one movable, on which are deposited vertical opaque bars. The lenses are positioned so that in the open state the bars are superimposed, thus allowing the wearer to see through the slits between the bars.
Method of operation: The rise of a high-intensity light source is detected by photocells that trigger a power pack which supplies energy to set off a charge in an explosive piston motor. The piston drives a cone-shaped wedge downward, causing the movable lens in each eyepiece to move laterally over the fixed lens to block out the light.
Results and conclusions: For the later model, a cylinder housing for a dimple motor appeared to meet repeatability requirements. The goggles were lighter in weight (about 1/2 lb.) and the power pack was lighter (1/2 lbs.) and smaller in size. There was also a reduction in required current. The vertical bars present resulted in nonacceptance of this item on OT&E.

C. Electro-optical (E-O)

1. Stressed-plate shutter

Manufacturer: Electro-Optical Systems, Inc.
Author: Hauser, S. M., et al. (4) and Williams, D. W. and B. C. Duggar (29)
Light transmission: Closed - 1% to 0.1% (density 2 to 3)
Open - less than 20% (density more than 0.7)
Operating time: To close - 75 to 125 microseconds when properly damped electrically at room temperature
Principle: Stressed-plate shutter is a Hayward C-3 glass plate mounted between a pair of Polaroid HN-22 filters. This assembly is bonded to a pair of horizontal tungsten carbide beams. Inserted vertically between both ends of the beams are stacks of piezoelectric ceramic wafers.
Method of operation: Under stressed conditions (voltage applied) the shutter is in the open state. When light flash is detected, stress is removed and the system closes.
Results and conclusions: Development objectives were met, but additional development was recommended. Open transmission is inadequate.

2. Electro-chemical light modulator

Manufacturer: Philco Research Division
Author: Aitken, J. F. (3)
Light transmission: Closed - less than 10% (density greater than 1)
Open - 20% (density 0.7)
Operating time: To close - 300 - 1000 microseconds
To open - 10 sec. to 5 minutes
Principle: Electro-chemical light modulator. Reversible electro-plating light shutter.
Method of operation: High-speed electroplating of a transparent optical material by an electric current triggered by a nuclear flash.
Results and conclusions: In the original cell design, difficulties were encountered in the fabrication of conducting glass plates, contact resistances, and heavily loaded parallel circuits. Design changes were made, but completed cells were not entirely satisfactory. All of the specifications could not be met. Additional development was recommended. It is not suitable at the present time (April 1962) for the Armed Services.

3. Kerr-type cell

a. Manufacturer: Electro-Optical Systems, Inc.
Author: Hauser, S. M., et al. (30) and Williams, D. W. and B. C. Duggar (29)
Light transmission: Closed - .0001 (density 6)
Open - about 10%
Operating time: To close - 1-2 microseconds
To open - not applicable, due to mechanical back-up shutter
Principle: Kerr cell and other polarizing devices
Method of operation: Glass cell, filled with a liquid, contains planar electrode mounted between a pair of crossed linear crystal polarizers. The liquid, usually nitrobenzene, rotates the plane of polarization when stressed by a voltage applied to the cell electrodes. When voltage is removed, a plane of polarization is no longer rotated and light is not transmitted. A mechanical back-up shutter is utilized to provide positive, long term closure.
Results and conclusions: Open transmission is not adequate; Kerr effect is temperature sensitive. Several factors impose restrictions on the size of the device.

b. Manufacturer: Electro-Optical Systems, Inc.
Author: Jenkins, R. J. and E. R. Schleiger (31)
Light transmission: Closed - 2.8% (density 1.5)
Open - 3.6% (density 1.4)
Telescope transmission - 35% (density .5)
Operating time: To close - 1 microsecond
To open - same as 3a.
Principle: Application of Kerr Cell to Battery Commander's Telescope M65, with mechanical back-up shutter.
Method of operation: Same as 3a.
Results and conclusions: Same as 3a.

4. Solid-state shutter

Manufacturer: Bausch and Lomb, Inc.
Author: Hensler, J. R. and E. C. Letter
Light transmission: Closed - 0.01% (density 4)
Open - 70% (density 0.13)
Operating time: To close- less than 25 microseconds
To open - unknown (probably manual)
Principle: Solid-state shutter. The evaporation of metallic film by electrical discharge.
Method of operation: The optical system is composed of a periscope containing lenses which are coated with aluminum film. Electrical discharges are capable of removing this film from the glass lenses since it is a conductive path for electrical discharges. This system is to be reopened by a mechanical cell replacement.
Results and conclusions: Unknown whether it has been tested.

5. VARAD

Manufacturer: Marks Polarized Corporation
Author: Marks Polarized Corporation (32)
Light transmission: Closed - 0.1% (density 3) to 1.3 x 10^{-5}% (density 6.9)
Open - 63% (density 0.2) to 31.5% (density 0.5)
Operating time: To close - 10 milliseconds
To open - in the millisecond range
Principle: A VARAD material is an electro-optical medium which has the property of varying its transmittance, absorbance, or reflectance of radiation in response to an applied electrical field. VARAD panels comprise two separate glass layers, each containing a transparent conducting layer, sealed around the edge to form a cell containing a dipole suspension in a fluid layer. Dipoles are submicroscopic, needle-like particles capable of interacting with light.
Method of operation: The VARAD panel becomes light transmissive upon application of an electric field between the transparent conductors. This causes the dipoles to align at right angles to the glass sheets, more or less parallel with the light rays. Upon removal of the electric field, the directions of the needle-like particles randomize. Dipoles in random directions absorb or reflect light.
Results and conclusions: Device prototype is under development.

6. Thin glass polarizer

Manufacturer: Southwest Research Institute
Author: Whitmore, F. C., et al (38)
Light transmission: Closed - unknown
Open - nearly 100% (density about 0)
Operating time: Unknown
Principle: Thin glass polarizer. An electrically closed shutter containing liquid crystal material.
Method of operation: A thin layer of a liquid crystal system is utilized in a venetian blind arrangement of thin glass plates. An electrical current would cause the system to act as a simple polarizer.

Results and conclusions: The experiments reported indicate that there is not enough information to allow an evaluation of this technic for the desired application.

7. Display

Manufacturer: General Dynamics/Pomona
Author: Sneed, R. J., et. al. (34)
Light transmission: Image intensity on an electroluminescent panel is limited to a safe and tolerable level at all times. Intensity of the transmitted image may be varied by varying the voltage across the panel.
Operating time: Not applicable
Principle: Display. An image converter responds to incident visible radiation and in turn produces a monochromatic visible image on an electroluminescent panel. The unit may be constructed so that it will make infrared light visible to provide night vision.
Method of operation: The solid state image converter consists of a sandwich configuration composed of photoconductive material, electroluminescent material and electrodes. The electrodes, located on on the object side of the photoconductive material and on the viewing side of the electroluminescent panel, consist of optically transparent and electrically conductive films. An opaque conductive layer is sandwiched between photoconductive and electroluminescent layers to prevent an optical feedback. The image incident on the surface of the photoconductive layer is reproduced on the viewing surface of the electroluminescent layer.
Results and conclusions: The unit is still in the laboratory stage and at present has poor resolution and degrades with age. The system may be suitable only for certain applications since it does not provide a directly viewed, full-color image. Refinements in the electroluminescent panels are expected to improve resolution.

8. On-off light valve

Manufacturer: General Electric Co.
Author: General Electric Co.
Light transmission: Undeveloped
Operating time: Undeveloped
Principle: On-off light valve
Method of operation: A reversible (or nonreversible) on-off light valve is triggered by an intense flash of light which closes the valve. In a reversible system, the valve opens after flash cessation. The light valve, which has no moving parts, depends on the rotation of optically active molecules sandwiched between polarizing sheets. Intense light changes the optical rotation of the molecules and causes extinction of the light polarized by the sandwiching sheets. Under ambient lighting conditions, molecules return to their normal state and open the valve. Since a physical process on a molecular level is involved, response time is exceedingly fast.
Results and conclusions: Unknown.

9. Electro-plastic material

Manufacturer: General Electric Co.
Author: General Electric Co.
Light transmission: Undeveloped
Operating time: Undeveloped
Principle: Electro-plastic material
Method of operation: A thin transparent plastic film is sandwiched between thin electrodes. Application of a high electric potential across the plastic (possibly followed by heating) results in a wrinkled, frosty surface which scatters light. The desired optical density is achieved by superposition of several sandwiches. The frost is removed and initial transmission is restored by melting the plastic.
Results and conclusions: This material is now being developed.

10. Recombined light

Manufacturer: Southwest Research Institute
Author: Whitmore, I. C. (33)
Light transmission: Closed - unknown
Open - about 50% (density 0.3)
Operating time: Unknown
Principle: Recombined polarized light. Kerr cell attached to a dual window optical system.
Method of operation: Extra-ordinary light rays lost in polarization of light is recovered and recombined with ordinary rays penetrating the polarizers by utilizing a front surface mirror and beam splitter. A Kerr cell for each channel is sandwiched between a pair of polaroid polarizers.
Results and conclusions: Further work was terminated because of the large size of the optical system and problems arising involving Kerr cell materials.

D. Explosive lens filter (ELF)

Manufacturer: Sandia Corp., Omnitech, Inc., Bermite Saugus Powder Co., and Douglas Aircraft Co.
Author: Jones, W. L. and J. F. Parker (8); Jacobs, E. P. (5); Johns Hopkins University (35); Chisum, G. T. and J. H. Hill (7); and Williams, D. W. and B. C. Duggar (29)
Light transmission: Closed - less than 0.1% (density greater than 3)
Open - about 85% (density about 0.07)
Operating time: To close - less than 203 microseconds
To open - manually
Principle: Explosive lens device. Explosively actuated light filter system (ELF)
Method of operation: This system contains goggles with clear lenses designed to close automatically upon a signal from a sensing unit. When an appropriate signal is received, an explosive charge drives a carbon colloid solution between layers of the lens, thus effectively blocking all light transmission.

Results and conclusions: The optical quality of this lens is satisfactory and it may be used at night. Visual acuity, phorias, and depth perception remain unchanged. Poor upward and downward fields of view and a distortion band across the top and bottom of the lens cause an unusual amount of head movement to maintain a normal overhead look-out doctrine and a proper scan of the instrument panel. Leakage of opaquing material occurs around the ELF lens frame. Difficulty has been encountered in unlocking the latch on the visor. It is in present use by the Navy as an interim device for flashblindness protection.

E. Phototropic (P)

1. Hackmanite

Manufacturer: Polacoat, Inc.
Author: Dreyer, J. F. (36)
Light transmission: Closed - 7.9% (colored form density 1.1)
Open - 23.5% (bleached form density 0.63)
Operating time: To close - 30 seconds
To open - 30 seconds
Principle: Hackmanite. Investigation of inorganic phototropic materials as a bioptic element applicable in high-density, storage-computer memories. Natural Hackmanite is pinkish colored when fresh, turns dark purple when exposed to ultraviolet radiation of 330 millimicrons, and becomes bleached by light of any wavelength.
Method of operation: A general evaluation of the various types of phototropic phenomenon is given regarding the application of phototropic materials to bioptic high-density storage media for computer memories. The organic "F" center-type phototropic systems were chosen as the area offering the greatest potential.
Results and conclusions: Operating time is too slow and transmission is not optically good enough. No visible changes after four months storage in darkness for either colored or bleached form. Material did not become fatigued after at least 314,680 reversals. Synthetic tenebrescent materials are now under study.

2. Indirectly-activated

Manufacturer: Edgerton, Germeshausen, & Grier, Inc., and National Cash Register Co.
Author: Barstow, F. E. and C. Lilliott (6); R. F. Durig, et al., (9)
Light transmission: Closed - 0.1% (density 3)
Open - 42% (density 0.38)
Operating time: To close - about 125 microseconds
To open - less than 2 seconds
Principle: Indirectly activated photochromic materials darken suddenly on exposure to ultraviolet light and revert to clear state when exposure ends.

Method of operation: The phototropic solution is confined in a layer only 0.010 inch thick between 2 optically ground and polished quartz wedges. Xenon flash tubes, positioned above and below the quartz wedges, when triggered provide the activating energy. Special filters protect the eye from the light emitted by the flash tubes but transmit the ultraviolet energy to the photochromic materials. The entire lens is uniform in density.

Results and conclusions: Additional development is recommended.

3. VADO

Manufacturer: Marks Polarized Corp.
Author: Marks Polarized Corp. (37)
Light transmission: Closed - 0.01% (density 4)
Open - 40% to 60% (density about 0.3)
Operating time: To close - at least milliseconds
To open - seconds
Principle: VADO modification. A resistive transparent film coated with thermotropic material
Method of operation: A flash of light striking a photocell is used to trigger the source of energy, stored in a bank of capacitors, which then discharges across the thermotropic film. Alternatively, the film may be activated by light energy.
Results and conclusions: Development is continuing.

4. Irreversible material

Manufacturer: Polacoat, Inc.
Author: Krekeler, J. H. (38)
Light transmission: Closed - 0.01% (density 0.4)
Open - 70% (density 0.15)
Operating time: To close - under 50 microseconds
To open - manually, less than 10 seconds.
Principle: Irreversible material. An irreversible protective device utilizing photothermosensitive material to be used in conjunction with a fixed filter contained in a goggle. The end result was a bi-lens goggle made of black rubber.
Method of operation: The phototropic compound is formulated as an irreversible system and then used as an interlayer laminated between 2 clear plastic films.
Results and conclusions: The life of the filter is temperature-dependent, but does have some stability at moderate temperatures. For storage, a temperature of 32° F. or less is required.

5. Rare earth

Manufacturer: Pittsburgh Plate Glass and Mellon Institute
Author: Goldish, J. H. (24)
Light transmission: Unknown
Operating time: To close - minutes
To open - approximately 30 minutes

Principle: Rare earth coating: Photochromic glass
Method of operation: The development of inorganic color centers in glass doped with rare earths is at present under study. The samples are sensitive to light at 2537 and 3650 angstroms.
Results and conclusions: Fatigue is a problem. The work is still in the laboratory stage.

6. Silver halide microcrystals

Manufacturer: Corning Glass Works
Author: Stookey, S. D. (39)
Light transmission: Closed - approximately 1% to 23% (variable) (density 2 to 0.64)
Open - approximately 85% (variable) (density about 0.065)
Operating time: To close - slow
to open - less than 2 minutes
Principle: Silver halide microcrystals are precipitated in glass. Some of the scientists at Corning believe that the very small size of these crystals imbedded in glass insures that the photolytic color center cannot diffuse away or grow into stable silver particles or react chemically to produce irreversible decomposition of silver halide.
Method of operation: When light strikes a plate of transparent glass impregnated with silver halide microcrystals, the glass darkens. The plate clears again to its original color when light is removed.
Results and conclusions: The silver halide remains permanently active without material fatigue. Too slow to offer much protection from flashblindness or retinal burn. Glass must be 1/4 inch thick to transmit 1% light under exposure to light.

7. Thiozone dyes

Manufacturer: American Optical Company
Author: American Optical Company
Light transmission: Variable density - maximum equal to or greater than 4.
Operating time: Activation and recovery - variable from a few seconds to many minutes.
Principle: Thiozone dyes. Reversible, organic dyes in a liquid state are impregnated into the pores of a transparent solid.
Method of operation: The transparent solids are activated by short wavelength visible and near ultraviolet light, turning blue when in the activated state.
Results and conclusions: These dyes are still in laboratory stage. Fast recovery is obtained at the expense of lowered optical density.

8. Triplet states

Manufacturer: TRW Systems (formerly Space Technology Laboratories, Inc.)
Author: Windsor, M. W., et al. (40)
Light transmission: Closed - variable 0.01% or more (density variable to 4 or less)
Open - unknown
Operating time: To close - approximately 100 microseconds. The speed with which such a filter darkens depends on the rate of arrival of the ultraviolet energy which activates it; therefore, closure time is variable.
Principle: Triplet states of aromatic compounds. Aromatic compounds pumped to triplet state by UV light absorb energy in the visible spectrum.
Method of operation: Aromatic hydrocarbons and their derivatives dissolved in a suitable plastic medium exhibit strong reversible photochromic effects on irradiation by UV light because of temporary excitation to the lowest triplet state. If, as often happens, the triplet-molecule absorbs visible light, the result is a decrease in transmission. Triplet molecules are unstable and in the absence of excitation return to the ground state. Thus, the process is reversible.
Results and conclusions: Fatigue studies show no detectable fatigue after 700 flashes for chrysene in polymethymethocrylate. Excitation by ultraviolet is favored over excitation by electron irradiation. The compound napthocoronene appears capable of giving good protection against flashblindness if activated by a 1000 Joule flash lamp. A system using the triplet state for eye protection from nuclear flashblindness has not yet been devised. Development is continuing.

9. Directly activated dynamic cell

Manufacturer: Polacoat, Inc.
Author: Willis, R. E. (41)
Light transmission: Function of incident energy and fluid flow rate
Operating time: Function of incident energy
Principle: Directly activated dynamic cell - goggles and windshield segment.
Method of operation of goggle: The device is a goggle which incorporates a double lens arrangement with provisions for flow of a phototropic fluid between the parallel transparent plates. Other components of the system include a reservoir for storage of the phototropic liquid and a pressure cell for forcing the liquid to circulate through the lenses as necessary. The fluid is photosensitive and has a capability for rapidly increasing its optical density when exposed to the high-intensity light levels of a nuclear weapon detonation. The fluid darkens when exposed to ambient daylight but at a much slower rate which dictates the need for continuous flow during operational use in daytime. Provisions are incorporated for a rapid flush of the darkened material after exposure to a nuclear flash. Three prototype goggles have been fabricated and improvements are to be incorporated in subsequent prototype items to be delivered for test and evaluation.

Method of operation of windshield segment: This is a double wall fluid cell which utilizes an irreversible photosensitive material having a capability for decreasing its transmittance on exposure to activating energy in the near ultraviolet wavelengths. The cell provides a protected viewing area of 6 x 8 inches and is designed to be mounted behind the aircraft windshield and to be used in conjunction with thermal curtains. Other components of the system include a motor-pump reservoir unit and flow-control unit. The motor-pump reservoir unit provides fluid propulsion and storage space for fresh and expended filter liquids. Since the filter liquids darken on exposure to sunlight as well as to a nuclear detonation, a variable slow flow of filter liquid through the windshield segment cell is controlled by the flow-control unit which has two modes of control, a continuously variable slow flow accomplished by rotation of a knob on the flow-control unit and a fixed high rate of flow accomplished by depressing this same knob when rapid clearing following a detonation is desired.

Results and conclusions: a. Goggle. The contract provides for delivery of 50 items for operational test and evaluation by SAC, TAC and ADC.

b. Windshield segment. A first prototype and 4 second prototype systems are being provided for engineering evaluations and test. Two prototype items have been received and are undergoing evaluation.

A prototype windshield segment has been tested by personnel of USAFSAM and NASL. The photochromic material was too insensitive to be of value as a directly activated protective device.

10. Dye-enzyme materials

Manufacturer: Not applicable
Author: Allinikov, S. (42)
Light transmission: Closed - approximately 0.31% (density 2.5)
Open - unknown
Operating time: Unknown
Principle: Dye-enzyme materials
Method of operation: The properties and behavior of several unique enzyme-dye combinations of phototropic materials have been investigated. Triphenylmethane dyes and the enzyme papain form a phototropic system which changes from a colorless to a highly colored state under the influence of ultraviolet light. This class of materials is undergoing further development.
Results and conclusions: This class of materials is also being studied by the Chemical Sciences Department, QUANTUM PHYSICS LABORATORY, Physical Research Division, TRW Systems, One Space Park, Redondo Beach, California.

REFERENCES

1. The flashblindness problem in naval aviation. Unpublished report. BioTechnology, Inc., Arlington, Va. (Undated).

2. Parker, J. F., Jr. Target visibility as a function of light transmission through fixed filter visors. Report 64-2, Contract Nonr-4185 (00), BioTechnology, Inc., Arlington, Va., Apr. 1964.

3. Burger, W. R., and H. C. Filer. Electromechanical goggle. ASD-TDR-63-451. Aeronautical Systems Division, Wright-Patterson AFB, Ohio, Sep. 1963, (DDC AD422477L).

4. Hauser, S. M., D. G. Marlow, and L. S. Smith. Design and fabrication of experimental stressed-plate shutter systems. Contract DA-04-495-ORD-1995, 1510 Phase I, Final report, U.S. Army Ordnance, Frankford Arsenal, Philadelphia, Pa., 20 May 1961,(DDC AD259451).

5. Jacobs, E. P. Test flight of pilots' flashblindness helmets, goggles, glasses, and associated systems. Fourth interim report ST35-40R-63. Bureau of Naval Weapons, Washington, D. C., 9 Aug.1963.

6. Barstow, F. E., and C. Lilliott. Development of flashblindness protective goggles. EG&G Report B-2288, Contract AF41(657)-315. Edgerton, Germeshausen, and Grier, Inc., Boston, Mass., Sep. 1961,(DDC AD447126).

7. Chisum, G. T. and J. H. Hill, Dynamic simulation of the A4D flashblindness protective system. NADC-MA 6312, U. S. Naval Air Development Center, Johnsville, Pa., 25 July 1963,(DDC AD414398).

8. Jones, W. L. and J. F. Parker. Flashblindness protection. ACLANT Medical Officers Symposium on BioMedical Effects of Nuclear Weapons. National Naval Medical Center, Bethesda, Md., 29 Oct. 1963.

9. Durig, R. F., R. C. Willett, and M. D. Sobottke. Development of an indirectly actuated, phototropic, flashblindnes, eye protective goggle. SEG-TDR-64-59. Final report Contract AF31(657)-10175. Systems Engineering Group, Wright-Patterson AFB, Ohio, Dec. 1964.

10. Minners, H. A., and N. L. Newton. A simple method of chorioretinal burn protection. Aerospace Medicine, 35: 627-632 (1964).

11. Wilson, C. L. Monocular eyeshield for use by combat crews. Headquarters Second Air Force (SAC), Barksdale AFB, La., 20 Mar. 1962.

12. Provost, J. R., and R. Noble. A monocular occluding system for flashblindness and retinal burn protection. NAEC-ACEL-516. Bureau of Naval Weapons, Washington, D. C., 14 Feb. 1964 ,(DDC AD430976).

13. Baltzer, D. H. and J. F. Dreyer. Ultraviolet and near infrared absorptive coating materials and techniques for their application. WADC-TDR-58-73. Wright Air Development Center, Wright-Patterson AFB, Ohio, Aug. 1958, (DDC AD203902).

14. Banet, L. Report on improvement of glass lenses for personnel safety equipment. Tech Memo No. 1, Lab Project 9400-44, Naval Applied Science Lab., Brooklyn, N.Y., 1 Oct. 1963, (DDC AD418357).

15. Banet, L. Report of development of plastic filters for welders. Tech Memo No. 2, Lab Project 9400-44, Naval Applied Science Lab., Brooklyn, N.Y., 10 Oct. 1963, (DDC AD419739).

16. Jupnik, H. Gradient density sunglasses. SEG-TDR-64-50. Systems Engineering Group, Wright-Patterson AFB, Ohio, Oct. 1964.

17. Jacobs, E. P. Test flight of pilots' flashblindness helmets, goggles, glasses and associated systems. First Interim Report ST35-8R-63, Bureau of Naval Weapons, Washington, D. C., 15 July 1963.

18. Hill, J. H. Measurement of spectral transmission characteristics of LRFG-58 goggles. NADC-MA-92. U. S. Naval Air Development Center, Johnsville, Pa., 7 Dec. 1959.

19. Moore, J. L. Test flight of pilots' flashblindness helmets, goggles, glasses, and associated systems; Fifth Interim Report. NATC Report of Test Results, ST-35-104R-63, Bureau of Naval Weapons, Washington, D.C., 17 Dec. 1963, (DDC AD425437L).

20. Colman, A. B. Design of an optical insert type 3R1. Technical Report No. 6404, U.S. Army Medical Biomechanical Research Lab., Walter Reed Army Medical Center, Washington, D. C., June 1964, (DDC AD602249).

21. Timm, W. Development of a device to provide protection for the eyes against the dazzle effect of a nuclear weapon. Final Report Contract DA-19-129-QM-1448 (O.I.9178). Mine Safety Appliances Company, Pittsburgh, Pa., 25 July 1960, (DDC AD254046).

22. Pisano, F. Feasibility study of an explosively actuated flash protection device. Report R-1640. Frankford Arsenal, Philadelphia, Pa., Jan. 1964, (DDC AD430250).

23. Moatz, D. R. and D. A. Jones. Flash protection system study (cartridge-actuated curtain shutters). Report SME-AA-35. Systems Management and Engineering Department, Fairchild Camera and Instrument Corp., Syosset, N.Y., 30 Oct. 1959, (DDC AD230252).

24. Goldish, L. H. A survey of light-activated optical-protection systems. Report No. E-1664, Massachusetts Institute of Technology, Cambridge, Mass., Oct. 1964.

25. Shades bask in the sun. Chemical Week, P. 3, 25 July 1964.

26. Electronic Corp. of America. Anti-glare shutter engineering manual. Contract AF33(616)-3045, Wright Air Development Center, Wright-Patterson AFB, Ohio, 1957.

27. Wayne-George Corp. High-speed electromechanical goggle. WADC-TR-59-114, Wright Air Development Center, Wright-Patterson AFB, Ohio, May 1959, (DDC AD215828).

28. Bowling, M. G. Evaluation of OT&E electromechanical goggles. Final report of project ADC/73AD/63-13, 4750 Test Squadron, Air Defense Command, Tyndall AFB, Fla., 22 Apr. 1963, (DDC AD404639).

29. Williams, D. W., and B. C. Duggar. Review of research on flashblindness, chorioretinal burns, countermeasures, and related topics. DASA-1576, Contract No. DA-49-146-XZ-242. Defense Atomic Support Agency, Washington, D. C., 15 Aug. 1965.

30. Hauser, S. M. Feasibility study and proposed engineering design of anti-flash device. Final technical report. Phase 1, Contract No. DA-04-495-ORD-1216, U.S. Army Ordnance, Frankford Arsenal, Philadelphia, Pa., 15 Sep. 1958, (DDC AD206838).

31. Jenkins, R. J. and E. R. Schleiger. Optical transmission measurements of an anti-flash system. Report TR-445, U.S. Naval Radiological Defense Laboratory, San Francisco, Calif., July 1960, (DDC AD245680).

32. VADO, Part B. Liquid dipole shutter. Quarterly Report No. 2, Contract No. NOas-59-6256-c, Marks Polarized Corp., Whitestone, N.Y., 5 Feb. 1960. (Obtainable through Bureau of Naval Weapons (RRMA-3), Washington, D. C.).

33. Whitmore, F. C., R. E. Linder, and W. W. Bradshaw. Dual channel optical system for use with low voltage Kerr cell. Final Report, Contract No. AF41(609)-2709. Southwest Research Institute, San Antonio, Tex., 31 Dec. 1965, (DDC AD627245).

34. Sneed, R. J., G. C. Knight, and E. Hartouni. Flash protection device. Final Report, Contract No. OA-19-129-QM-1965. Physics and Infrared Section, General Dynamics/Pomona, Pomona, Calif., Oct. 1963.

35. Johns Hopkins University. High speed photography coverage of ELF lens assembly firing tests. Report No. TS-1048, Bureau of Naval Weapons, Washington, D. C., Apr. 1965.

36. Dreyer, J. F. Investigation of inorganic phototropic materials as a bi-optic element applicable in high density storage computer memories. ASD-TDR-62-305, Aeronautical Systems Division, Wright-Patterson AFB, Ohio, Apr. 1962, (DDC AD277793).

37. VADO- Photo-thermotropic variable density optical shutter. Final Report, Contract No. NOas-59-6256-c, Marks Polarized Corp., Whitestone, N.Y., 26 Apr. 1961, (DDC AD264341).

38. Krekeler, J. H. Development of an irreversible photo-thermosensitive ophthalmic nuclear flash protective device. ASD-TDR-63-658. Aeronautical Systems Division, Wright-Patterson AFB, Ohio, Oct. 1963, (DDC AD424140).

39. Stookey, S. D. Some unusual properties of microcrystals in glass. Presentation at the annual meeting of the American Physical Society, New York, N. Y. Corning Glass Works, Corning, N.Y., 24 Jan. 1964.

40. Windsor, M. W., et al. Research on triplet states and photochromism. Report No. 4, Contract No. AF41(609)-1457, Space Technology Labs., Redondo Beach, Calif., 1963, (DDC AD434239).

41. Willis, R. E. The Air Force flashblindness program. 5 Feb. 1965.

42. Allinikov, S., and L. L. Nolen. Automatically responsive chemical optical shutters. RTD-TDR-63-4152. Research and Technology Division, Wright-Patterson AFB, Ohio, Mar. 1964, (DDC AD435685).

BIBLIOGRAPHY

1. Abbott, H. M. Thermochromism and phototropism: An annotated bibliography. Special Bibliography SB-63-41. Lockheed Missiles and Space Co., Sunnyvale, Calif., Apr. 1963, (DDC AD420150).

2. Aircraft flash/thermal protective system (U). Douglas Aircraft Division, Long Beach, Calif., July 1962, (DDC AD329836). CONFIDENTIAL.

3. Aitken, J. F. Electrochemical light modulator. MRL-TDR-62-29. Aerospace Medical Research Labs., Wright-Patterson AFB, Ohio, Apr. 1962, (DDC AD283118).

4. Allen, R. G. Jr., et al. Production of chorioretinal burns by nuclear detonations and tests of protective devices and phototropic materials (U). POR-2014, Vol. I, Defense Atomic Support Agency, Washington, D. C., (DDC AD359129L). SECRET/FORMERLY RESTRICTED DATA.

5. Armistead, W. H., and S. D. Stookey. Photochromic silicate glasses sensitized by silver halides. Science, 144: 150-154, (1964).

6. Ban, G., et al. Study and development of a solid state viewing device for suppression of flashblindness and retinal burn during nuclear weapons bursts. Contract No. DA 11-022-ORD-4207, Zenith Radio Corp., Chicago, Ill., U. S. Army Tank-Automotive Center, Center Line. Mich.

7. Barstow, F. E., and P. McSweeny. Nuclear weapons and associated eye effects (U). AMRL-TDR-63-101. Aerospace Medical Research Labs., Wright-Patterson AFB, Ohio, Oct. 1963, (DDC AD345837). SECRET.

8. Bowman, R. E., et al. Research and reports on photochromic materials which may be used as eye-protective devices. Contract Report, National Cash Register Co., Dayton, Ohio, Apr. 1963, (DDC AD427601).

9. Bowman, R. E. Effort to evolve a method of eye protection from flashblindness. Contract AF41(609)-2292. National Cash Register Co., Dayton, Ohio, 30 June 1964.

10. Britten, A. J. Eye-protective devices. Tank Fire Control Division, Frankford Arsenal, Philadelphia, Pa., Nov.-Dec. 1964.

11. Brown, G. H. Kinetic studies of phototropic reactions of triphenylmethane leuconitriles. AMRL-TDR-62-84. Aerospace Medical Research Labs., Wright-Patterson AFB, Ohio, Aug. 1962, (DDC AD287451).

12. Brown, G. H. Phototropy: A literature review. WADC-TR-59-436. Wright-Patterson AFB, Ohio, Aug. 1962.

13. Brown, J. L. The use of colored filter goggles for protection against flashblindness. NADC-MA-5917. Aviation Medical Acceleration Lab., U.S. Naval Air Development Center, Johnsville, Pa., 22 Oct. 1959, (DDC AD229350).

14. Chisum, G. T., and J. H. Hill. Photoelectric and psychophysical measures of nuclear weapons flashes (u). POIR 2016. Defense Atomic Support Agency, Feb. 1963, (DDC AD335997). SECRET.

15. Claesson, S. Flash photolysis study of the reactions between photo-excited fluorescein and selected substrates. Final Report Contract No. DA-91-591-EUC-2162, 01-26528-B, U.S. Department of Army, European Research Office, 31 Jan. 1963.

16. Coleman, R. A. Literature review of near infrared attenuating media. MRL-TDR-62-54. Aerospace Medical Research Labs., Wright-Patterson AFB, Ohio, May 1962, (DDC AD283443).

17. Coleman, R. A. Study of chromotropic properties or colorants. TR-TS-129, Clothing and Organic Materials Division, U. S. Army Natick Labs., Natick, Mass., Feb. 1964, (DDC AD449505).

18. Collins, R. D., and R. F. Durig. Development of an eye protective device, flashblindness phototropic, indirectly activated windshield segment. Monthly Progress Report, Contract No. AF33(657)-13420, National Cash Register Co., Dayton, Ohio, 10 Jan. 1965.

19. Collins, R. D., and C. W. Kruer. Improved sensor trigger circuitry for the electromechanical goggle (U). National Cash Register Co., Dayton, Ohio, May 1964, (DDC AD352201). SECRET RESTRICTED DATA.

20. Data on American Optical Co. reversible photochromic systems. American Optical Co., Research Center, Southbridge, Mass., June 1963.

21. Design, develop and fabricate items for flashblindness protective systems.
21. Interim Report No. 2, Contract No. NOw-63-0487-c. Omnitech, Inc., Dudley, Mass., 1 May 1963, (DDC AD305946L).

22. Design, develop and fabricate items for flashblindness protective systems. Interim Report No. 3, Contract No. NOw-63-0487-c. Omnitech, Inc., Dudley, Mass., 1 June 1963, (DDC AD418624L).

23. Design, develop and fabricate items for flashblindness protective systems. Interim Report No. 4, Contract No. NOw-63-0487-c. Omnitech, Inc., Dudley, Mass., 1 July 1963, (DDC AD418626L).

24. Design, develop and fabricate items for flashblindness protective systems. Interim Report No. 5, Contract No. NOw-63-0487-c. Omnitech, Inc., Dudley, Mass., 1 Aug. 1963, (DDC AD418625L).

25. Design, develop and fabricate items for flashblindness protective systems (U). Final Report Contract No. NOw-63-0487-c. Omnitech, Inc., Dudley, Mass., 29 Oct. 1963, (DDC AD346545). CONFIDENTIAL.

26. Dessauer, R., and J. P. Paris. Photochromism. In Noyes, W. A., G. S. Hammond, and J. N. Pitts (eds.). Advances in photochemistry, pp. 275-321. New York: Interscience Publishers, 1963.

27. Development of a photothermotropic device. Final Report Contract No. NOw-61-0391-c. Marks Polarized Corp., Whitestone, N. Y., 26 June 1962.

28. Development of a photothermotropic device (U). Final Report Contract No. NOw-63-0491-c. Marks Polarized Corp., Whitestone, N.Y. CONFIDENTIAL.

29. Development and testing of aircrew equipment for the suppression of nuclear flashblindness. Interim Report No. 6, Contract NOw-62-0815-c. Omnitech, Inc., Dudley, Mass., Apr. 1963.

30. Development and testing of aircrew equipment for the suppression of nuclear flashblindness. Interim Report No. 7, Contract No. NOw-62-0815-c. Omnitech, Inc., Dudley, Mass., Apr. 1963.

31. Development and testing of aircrew equipment for the suppression of nuclear flashblindness. Interim Report No. 10, Contract No. NOw-62-0815-c. Omnitech, Inc., Dudley, Mass., Apr. 1963.

32. Development of a photothermotropic device (U). Final Report Contract No. NOw-62-0637-c. Marks Polarized Corp., Whitestone, N.Y., 13 May 1963. CONFIDENTIAL.

33. Dorion, G., and L. Weissbein. Discovery (Photochromism). Feb. 1963.

34. Dreyer, J. F., and R. Harries. Phototropic and photochemical ophthalmic light filters (U). Final Report 63, Task No. 630103, USAF School of Aerospace Medicine, Brooks AFB, Tex., Nov. 1963, (DDC AD350681L). SECRET.

35. Dreyer, J. F., and R. Harries. Phototropic and photochemical ophthalmic light filters (U). AMRL-TDR-63-24. Aerospace Medical Research Labs., Wright-Patterson AFB, Ohio, Feb. 1963, (DDC AD336875). SECRET.

36. Dreyer, J. F. Self-attenuating ophthalmic filter (U). WADC-TR-60-632. Wright Air Development Center, Wright-Patterson AFB, Ohio, Feb. 1961, (DDC AD322820L). SECRET.

37. Dreyer, J. F. Salt-isomerism type phototropic self-attenuating ophthalmic filters (U). MRL-TDR-62-31. Medical Research Labs., Wright-Patterson AFB, Ohio, Mar. 1962, (DDC AD329380L). SECRET.

38. Dreyer, J. F. Development of a means to provide protection for the eyes against the dazzle effects of nuclear detonations. Quarterly Report No. 3, Polacoat Project QM-5, Polacoat, Inc., Blue Ash, Ohio, 30 Sep. 1960, (DDC AD447113).

39. Dreyer, J. F. Development of a means to provide protection for the eyes against the dazzle effects of nuclear detonations. Quarterly Report No. 4, Polacoat Project QM-5, Polacoat, Inc., Blue Ash, Ohio, 30 Dec. 1960, (DDC AD298225).

40. Dreyer, J. F. Development of a means to provide protection for the eyes against the dazzle effects of nuclear detonations. Quarterly Report No. 5, Polacoat Project QM-5, Polacoat Inc., Blue Ash, Ohio, 31 Mar. 1961, (DDC AD446865).

41. Dreyer, J. F. Feasibility study and design of a self-attenuating light valve. WADC-TR-59-81, Wright Air Development Center, Wright-Patterson AFB, Ohio, Oct. 1959.

42. Dreyer, J. F. Feasibility study and design of a self-attenuating light valve. WADD-TR-60-827, Wright Air Development Division, Wright-Patterson AFB, Ohio, Feb. 1961, (DDC AD265431).

43. Feaheny, D. E., and D. Wilburn. Survey of flashblindness and retinal burn protection (U). OTAC Report RR-26. Ordnance Tank-Automotive Command, Detroit Arsenal, Center Line, Mich., June 1960. SECRET.

44. Feasibility study on the application of color center phenomena in a solid state viewing device to prevent flashblindness and retinal burn. Report No. 3, Contract No. DA-11-022-3468, Zenith Radio Corp., Chicago, Ill., 25 Mar. 1961.

45. Fox, R. E. Research reports and test items pertaining to eye protection of aircrew personnel. Contract No. AF41(657)-215, National Cash Register Co., Dayton, Ohio, Apr. 1961, (DDC AD440226).

46. Fox, R. E. Development of photoreactive materials for eye-protective devices. SAM Report 61-67, Apr. 1961.

47. Frazer, R. E. Improvements in graded neutral density films for attenuation of visible light by ophthalmic lenses. AMRL Memo V-20. Aerospace Medical Research Labs., Wright-Patterson AFB, Ohio, Nov. 1962, (DDC AD292974).

48. Gardner, N. Protection of aircrew personnel against flashblindness. Tech. Note Mech. Eng. 395, Royal Aircraft Establishment. The Secretary, Ministry of Aviation, London, W. C. 2, Feb. 1964, (DDC AD351841).

49. Gulley, W. E. Evaluation of eye protection afforded by an electromechanical shutter. WT-1429, DASA, Washington, D. C., 29 Apr. 1960.

50. Harries, R. W. Development of a one-way phototropic-thermotropic ophthalmic nuclear flash protector (U). ASD-TDR-61-578. Aerospace Systems Division, Wright-Patterson AFB, Ohio, Oct. 1961, (DDC AD339793). SECRET.

51. Harries, R. W. The dynacell and focal plane concepts of phototropic systems applications to ophthalmic nuclear flash protection devices. Report MRL-TDR-62-46. Medical Research Labs., Wright-Patterson AFB, Ohio, May 1962, (DDC AD284059).

52. Hatheway, D. L., and A. O. Mirarchi. Study of eye effects associated with nuclear detonations (U). AMRL-TDR-63-114. Aerospace Medical Research Labs., Wright-Patterson AFB, Ohio, Nov. 1963, (DDC AD345853). SECRET RESTRICTED DATA.

53. Hauser, S. M. Compensation for polarization effects during extended operation of voltage stressed Kerr cells. Contract No. DA-04-495-ORD-1453, 280 Final Report, U.S. Army Ordnance, Frankford Arsenal, Philadelphia, Pa., 6 Apr. 1959, (DDC AD215188).

54. Hensler, J. R., and E. C. Letter. Feasibility study for the development of a solid state optical viewing device for the suppression of flashblindness and thermal eye burn incurred during nuclear weapons bursts. Report 3rd Quarter Contract No. DA-30-069-ORD-3097 OTAC, Bausch and Lomb, Inc., Rochester, N.Y., 1 Apr. 1961.

55. Hensler, J. R., and E. C. Letter. Feasibility study for the development of a solid state optical viewing device for the suppression of flashblindness and thermal eye burn incurred during nuclear weapons bursts. Summary Report Contract No. DA-30-069-ORD-3097 OTAC, Bausch and Lomb, Inc., Rochester, N.Y., July 1961.

56. Hensler, J. R., and E. C. Letter. Feasibility study for the development of a solid state optical viewing device for the suppression of flashblindness and thermal eye burn incurred during nuclear weapons bursts. Phase II. Final Report Contract No. DA-30-0690ORD-3097 OTAC, Bausch and Lomb, Inc., Rochester, N.Y., 1 Apr. 1962.

57. Hill, J. H., and G. T. Chisum. Flashblindness protection. Aerospace Med., 33:958, (1962).

58. Hill, J. H., and G. T. Chisum. Flashblindness: A problem of adaptation. NADC-MA-6327, U. S. Naval Air Development Center, Johnsville, Pa., 4 Dec. 1963, (DDC AD429241).

59. Horn, R. E., and R. D. Metcalf. Flashblindness during nuclear operations (U). WADC-TR-58-642. Wright Air Development Center, Wright-Patterson AFB, Ohio, Dec. 1949, (DDC AD338028). CONFIDENTIAL RESTRICTED DATA.

60. Jacobs, E. P. Test flight of pilots' flashblindness helmets, goggles, glasses and associated systems. Second Interim Report ST35-9R-63, Bureau of Naval Weapons, Washington, D. C., 9 July 1963.

61. Konitzer, J.,R. Jarka, and H. N. Hersh. Feasibility study on the application of color center phenomenon in a solid state viewing device to prevent flash-blindness and retinal burn. Final Contract Report, Ordnance Tank-Automotive Command, Detroit, Mich., 11 July 1961.

62. Kropp, J. L. Research on phototropic dye enzyme systems. First Quarter Informal Progress Report. Contract No. AF33(657)-11708, Aeronautical Systems Division, Wright-Patterson AFB, Ohio, 26 Jan. 1964.

63. Kropp, J. L. Research on phototropic dye enzyme systems. Second Quarter Informal Progress Report, Contract No. AF33(657)-11708, Aeronautical Systems Division, Wright-Patterson AFB, Ohio, 24 Apr. 1964.

64. Kropp, J. L. Research on phototropic dye enzyme systems. Third Quarter Informal Progress Report, Contract No. AF33(657)-11708, Aeronautical Systems Division, Wright-Patterson AFB, Ohio, 27 July 1964.

65. Kropp, J. L. Research on phototropic dye enzyme systems. Fourth Quarter Informal Progress Report, Contract No. AF33(657)-11708, Aeronautical Systems Division, Wright-Patterson AFB, Ohio, 28 Oct. 1964.

66. Laliberti, A. Development of eye, head or face protective devices. Contract NOas-59-6124c. American Optical Co. Department of the Navy, Bureau of Aeronautics, Washington, D.C., (DDC AD439822L).

67. Lappin, P. W. Eye protection from nuclear flashes afforded by a one percent fixed filter (U). AMRL-TDR-63-38. Aerospace Medical Research Labs., Wright-Patterson AFB, Ohio, May 1963, (DDC AD339978). SECRET.

68. Lappin, P. W. F100F/6AM 83B simulation (Operation Small Boy) (U). POR-2249, Defense Atomic Support Agency, Washington, D. C., Feb. 1963. SECRET.

69. Laxar, K. V. Critical visual areas of explosive-activated lens filter (ELF) system for protection of flashblindness. USNMRL Memo 64-1. U.S. Naval Medical Research Lab., Bethesda, Md., 15 Jan. 1964, (DDC AD422740).

70. Loper, L. R. Eye protection from nuclear flash (U). Report NS-25-61. In Department of Defense Armor Symposium (U), June 1960. SECRET.

71. Lowry, E. M. Feasibility study of the explosive lens anti-flash system for use in fire control optical instruments. BPC Report 330, Bermite Powder Co., Saugus, Calif., July 1963, (DDC AD427262).

72. Matoush, W. R. The non-lethal hazard in Air Defense Command operations (U). Operations Analysis Tech. Memo. 25. Hq., Air Defense Command, Ent AFB, Colo., 31 Aug. 1960. SECRET RESTRICTED DATA.

73. Mayer, H. L., R. M. Frank, and F. Richey. Point image spread function for nuclear eyeburn calculation. DASA-1528, C-72-64-(U)-1. Defense Atomic Support Agency, Washington, D. C., 24 June 1964.

74. Metz, F. I. Development of systems for automatic reversible control of intensity of visible radiation through transparent materials. MRI Project 2477-c, Contract No. NOw-61-0587-d, Midwest Research Institute, Kansas City, Mo., 26 July 196, (DDC AD261272).

75. Monahan, T. I., and W. L. Derksen. Progress in thermal radiation studies. Jan.-Mar. 1962. Lab. Projects 5046-2, 5046-3, 5046-16, Progress Report 27, Material Lab., New York Naval Shipyard, Brooklyn, N.Y., Mar. 1962.

76. Muller, A. Minimum distances for retinal burn (U). AMRL-TDR-63-56. Aerospace Medical Research Labs., Wright-Patterson AFB, Ohio, June 1963, (DDC AD343883). SECRET RESTRICTED DATA.

77. Nuclear radiation guide. Biomedical Laboratory, Wright-Patterson AFB, Ohio, TDR-62-61, Nov. 1962, (DDC AD410890).

78. O'Brien, S. J., and L. Weissbein. Attenuation of thermal radiation with phototropic colorants. Final Report Contract No. DA-19-129-QM-1438 (01-9170), American Cyanamid Co., Bound Brook, N.Y., 4 Aug. 1960.

79. Parker, J. F., Jr. Flashblindness protection for naval aviators (U). Contract Report No. 3445 (00). Matrix Corporation, Arlington, Va., Dec. 1962. SECRET.

80. Parkhurst, D. J. Operational test and evaluation of phototropic goggles. 4750 Test Squadron, Tyndall AFB, Fla., 13 Nov. 1963, (DDC AD428073).

81. Photochromic glass. Report No. 1. Corning Glass Works, Corning, N.Y., 1964.

82. Photochromic film, preliminary data. Market Development Department, Commercial Development Division, American Cyanamid Co., Stamford Research Labs., Stamford, Conn.

83. Photochromism and phototropism. Department of Commerce, National Bureau of Standards, Washington, D. C., Nov. 1964, (Available from Clearinghouse for Federal Scientific and Technical Information, Springfield, Va.)

84. Porter, G., and J. W. Hilpern. Decay of the triplet state. AF EOAR Grant 62-113. Cambridge Research Labs., Cambridge, Mass., through the European Office, Aerospace Research, USAF, 30 Sep. 1963, (DDC AD427019).

85. Radler, R. Inorganic phototropic materials for high density computer memories. ASD-TDR-63-172. Aeronautical Systems Division, Wright-Patterson AFB, Ohio, Mar. 1963, (DDC AD407796).

86. Research capabilities to perform systematic and fundamental work on developing a transparent semi-conductor junction as an eye protective device. General Dynamics, Pomona, Calif., Reference REP 41-609-65-281, Commerce Business Daily, 12 May 1965.

87. Ruderman, W. Development of rapid closure electro-optical crystal shutter. Report No. 5013-FR-62, Isomet Corp., Palisades Park, N.J., 10 Sep. 1962.

88. Russell, J. L. The temporary blinding effect of flashes of light. RAE Report E&I 1085. Royal Aircraft Establishment, South Farnsborough, Great Britain, Oct. 1937.

89. Servoss, W. C., and R. A. Foust. Development of a system to protect aircraft, personnel, and equipment from intense thermal radiation. Quarterly Report No. 1, Contract NOas-59-6112-c, MRI Project No. 2270-C, Midwest Research Institute, Kansas City, Mo., 16 June 1959, (DDC AD232246).

90. Servoss, W. C., and R. A. Foust. Development of a system to protect aircraft, personnel, and equipment from intense thermal radiation. Quarterly Report No. 2, Contract No. NOas-59-6112-c, MRI Project No. 2270-C, Midwest Research Institute, Kansas City, Mo., 16 Sep. 1959, (DDC AD227984L).

91. Servoss, W. C., and R. A. Foust. Development of a system to protect aircraft, personnel, and equipment from intense thermal radiation. Quarterly Report No. 3, Contract NOas-59-6112-c, MRI Project No. 2270-C, Midwest Research Institute, Kansas City, Mo., 2 Dec. 1959, (DDC AD232135).

92. Servoss, W. C., and R. A. Foust. Development of a system to protect aircraft, personnel, and equipment from intense thermal radiation. Supplement to Quarterly Report No. 2, Contract No. NOas-59-6112-c, MRI Project No. 2270-C, Midwest Research Institute, Kansas City, Mo., 16 Sep. 1959, (DDC AD228564).

93. Servoss, W. C., and R. A. Foust. Development of a system to protect aircraft, personnel, and equipment from intense thermal radiation. Final Report Contract No. NOas-59-6112-c, MRI Project No. 2270-C, Midwest Research Institute, Kansas City, Mo., 3 Feb. 1960, (DDC AD234901).

94. Smith, E. G. The tactical implications of flashblindness and chorioretinal burns caused by nuclear explosions. Part I, Flashblindness (U). Report 18/58. Army Operational Research Group, Department of the Scientific Advisor to the Army Council, Great Britain, Nov. 1958. CONFIDENTIAL.

95. Smith, E. G. The tactical implications of flashblindness and chorioretinal burns caused by nuclear exnolsions. Part II, Chorioretinal burns (U). Report 3/59. Army Operational Research Group, Department of the Scientific Advisor to the Army Council, Great Britain, Feb. 1959. CONFIDENTIAL.

96. Space vehicle guidance investigations exploratory development program. Technical Documentary Report R-436, Section 4.4. Massachusetts Institute of Technology, Cambridge, Mass., Feb. 1964.

97. Symposium on reversible photochemical processes. Preprint, U.S. Army Research Office, Duke Univesity, Durham, N.C., 16-18 Apr. 1962.

98. Technical proposal for high light level eye protection for astronauts. Military Contract Proposal. Advanced Development Division, National Cash Register Co., Dayton, Ohio, Aug. 1962.

99. Thomsen, R. K. Optimization of the ELF goggle (U). Bermite Powder Co., Saugus, Calif., 1 Apr. 1964, (DDC AD351454L). CONFIDENTIAL.

100. VADO, Part A. A phototropic variable density optical shutter. Quarterly Report No. 2, Contract No. NOas-59-6256-c, Marks Polarized Corp., Whitestone, N.Y., 1959. (Obtainable through Bureau of Naval Weapons (RRMA-3), Washington, D.C.).

101. Van Voorhis, J. J. A feasibility study of photochromic goggles for eye protection (U). ASD-TDR-61-317. Aeronautical Systems Division, Wright-Patterson AFB, Ohio, July 1961, (DDC AD339734). SECRET RESTRICTED DATA.

102. Van Voorhis, J. J. Study of photochromic materials for improved optical lens element. NADC-MA-6317. U.S. Naval Air Development Center, Johnsville, Pa., 10 Sep. 1963, (DDC AD425949L).

103. Van Voorhis, J. J. Nuclear flash early time histories - Operation Dominic (U). AMRL-TDR-63-73. Aerospace Medical Research Labs., Wright-Patterson AFB, Ohio, July 1963, (DDC AD340334). SECRET RESTRICTED DATA.

104. Volman, D. H. Sixth informal photochemistry conference. Final Report, Project No. 4544-C, on Grant No. DA-ARO-(D)-31-124-G503. Army Research Office, Durham, N. C., 15 July 1964, (DDC AD603537).

105. White, A. B. Nuclear flash discrimination and triggering (U). In Yoder, R. R. (ed.). Procedure of the research and development symposium on eye protection from nuclear blast (U). Edgerton, Germeshausen, and Grier, Inc., Boston, Mass., 15 Dec. 1959. SECRET RESTRICTED DATA.

106. Windsor, M. W., et al. Research on triplet states and photochromism. Report No. 2, Contract No. AF41(609)-1457. Space Technology Labs., Redondo Beach, Calif., 1962, (DDC AD600218).

107. Windsor, M. W., et al. Research on triplet states and photochromism for flashblindness protection. Report No. 6, Contract No. AF41(609)-2425. TRW Systems (formerly Space Technology Labs.), Redondo Beach, Calif., Apr. 1965, (DDC AD470908).

108. Wray, J. L. Model for prediction of retinal burns. DASA 1282. Defense Atomic Support Agency, Washington, D. C., 1 Feb. 1962, (DDC AD277363).

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13. ABSTRACT

A bibliography of eye protection from flashblindness and retinal burn is compiled from work that has been done in this area. In addition, each principle of eye protection is explained and the most significant examples of each principle are given. Some fixed filters worn during daylight hours will protect the eyes from flashblindness and retinal burn. Protection for the eyes still remains unsolved for scotopic vision.

14. KEY WORDS	LINK A		LINK B		LINK C	
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Flashblindness protection						
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